the contrary, it would be harmful, and conscious animals would have ceased long ago to survive. The very fact that consciousness is of such high value in the bionomy of an animal renders it obvious that it must be subject to law. Accordingly it appears to us regulated as do the functions of protoplasm. Hence to certain modern thinkers it presents itself as a function of protoplasm, or, as it may be better stated, as a state or condition of protoplasm.

The internal evidence of consciousness, however, is against this view and presents to us conscious actions as depending upon the consciousness. As before stated I believe that this evidence must be accepted. Now all the sensations of consciousness are derived from physical force, and all the acts of consciousness are manifested through physical force; hence if it has any real power consciousness must be able to change the form of energy. Unless we accept this doctrine, we must give up all belief in free-will and adopt the automaton theory of life. Is not the more reasonable explanation that which is based upon all the contents of our consciousness rather than that which we can draw by discarding the internal evidence which consciousness brings us? The hypothesis which I offer for your consideration is this:

Consciousness has the power to change the form of energy, and is neither a form of energy nor a state of protoplasm.

By this hypothesis there are two fundamentally different things in the universe, force and consciousness. You ask why I do not say three, and add matter? My answer is that we do not have, and never have had, any evidence whatever that matter exists. All our sensations are caused by force and by force only, so that the biologist can say that our senses bring no evidence of matter. The concept 'matter' is an irrational transfer of notions derived from the gross molar world of the senses to the molecular world. Faraday long ago pointed out that nothing was gained and much lost by the hypothesis of material atoms, and his position seems to me impregnable. It would be a great contribution to science to kill off the hypothesis of matter as distinct from force.

To conclude: The universe consists of force and consciousness. As consciousness by our hypothesis can initiate the change of the form of energy, it may be that without consciousness the universe would come to absolute rest. Since I close with a bold speculation let my last words recall to you that my text is: Investigate consciousness by comparative observations. Only from observation can we know. Correct, intelligent, exhaustive observation is our goal. When we reach it human science will be completed.

CHARLES SEDGWICK MINOT.
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*RECENT PROGRESS IN AMERICAN BRIDGE CONSTRUCTION.**

IN view of the great achievements in engineering construction which characterized the latter part of the nineteenth century in America, it seems appropriate to give a brief review of the most recent progress in one of its departments, that of bridge construction. It appears to be the more fitting since the place of this meeting of the Association is the greatest center of production of the material which constitutes the bulk of that used for modern bridges.

The application of scientific principles to the construction of bridges is more complete to-day than ever before. This statement applies to the specified requirements

* Address of the Vice-president and Chairman of Section D—Mechanical Science and Engineering—of the American Association for the Advancement of Science, Pittsburgh Meeting, June 28–July 3, 1902.

which the finished structure must fulfill, the design of every detail to carry the stresses due to the various loads imposed, the manufacture of the material composing the bridge, the construction of every member in it, and finally the erection of the bridge in the place where it is to do its duty as an instrument of transportation.

A close study of the economic problems of transportation in the United States and the experimental application of its results led the railroad managers to the definite conviction that, in order to increase the net earnings while the freight rates were slowly but steadily moving downward, it was necessary to change the method of loading by using larger cars drawn by heavier locomotives, so as to reduce the cost of transportation per train mile. While these studies had been in progress for a number of years and there was a gradual increase in the weight of locomotives, it is only within the past five years that the test was made, under favorable conditions and on an adequate scale, to demonstrate the value of a decided advance in the capacity of freight cars and in the weight of locomotives for the transportation of through freight. The test was made on the Pittsburgh, Bessemer and Lake Erie Railroad, which was built and equipped for the transportation of iron ore from Lake Erie to Pittsburgh and of coal in the opposite direction.

When this economic proposition was fairly established, it was wonderful to see how railroad managers and capitalists met the situation, by investing additional capital for the newer type of equipment, and for the changes in road bed and location necessarily involved by that in the rolling stock. Curves were taken out or diminished, grades were reduced, heavier rails were laid, and new bridges built, so that practically some lines were almost rebuilt. The process is still going on and money by the hundred millions is involved in the transformation and equipment of the railroads. Some impression of the magnitude of the change in equipment may be gained from the single fact, that one of the leading railroads has within a few years expended more than twenty millions of dollars for new freight cars alone, all of which have a capacity of 100,000 pounds. The form of loading for bridges almost universally specified by the railroads of this country consists of two consolidation locomotives followed by a uniform train load. These loads are frequently chosen somewhat larger than those that are likely to be actually used for some years in advance, but sometimes the heaviest type of locomotives in use is adopted as the standard loading. The extent to which the specified loadings have changed in eight years may be seen from the following statement based on statistics compiled by Ward Baldwin and published in the *Railroad Gazette* for May 2, 1902.

Of the railroads whose lengths exceed 100 miles, located in the United States, Canada and Mexico, only 2 out of 77 specified uniform train loads *exceeding* 4,000 pounds per linear foot of track in 1893, while in 1901, only 13 out of 103 railroads specified similar loads *less* than 4,000 pounds. In 1893, 37 railroads specified loads of 3,000 pounds and 29 of 4,000 pounds, while in 1901, 4,000 pounds was specified by 50, 4,500 pounds by 14, and 5,000 pounds by 17 railroads. The maximum uniform load rose from 4,200 in 1893 to 6,600 pounds in 1901.

In a similar manner in 1893 only 1 railroad in 75 specified a load on each driving wheel axle *exceeding* 40,000 pounds, while in 1901 only 13 railroads out of 92 specified *less* than this load. In 1893 only 21 of the 77 railroads specified similar loads exceeding 30,000 pounds. The maximum load on each driving wheel axle rose from

44,000 pounds in 1893 to 60,000 pounds in 1901.

The unusual amount of new bridge construction required caused a general revision of the standard specifications for bridges, the effect of which was to include the results of recent studies and experiment, and to eliminate some of the minor and unessential items formerly prescribed.

Meanwhile another movement was in progress. Experience having shown the great advantage of more uniformity in various details and standards relating to the manufacture of bridges both in reducing the cost and the time required for the shop work, an effort was begun to secure more uniformity in the requirements for the production and tests of steel, which is the metal now exclusively employed in bridges.

The American Section of the International Association of Testing Materials is bringing together through its investigations and discussions a mass of selected information on the relations of chemical composition, heat treatment, mechanical work, etc., to the physical properties of steel as well as of other metals used in structures and for mechanical purposes.

The thorough digest of these results of scientific research and practical tests, and the preparation and adoption of standard specifications for different classes of material, are confidently expected to eliminate many old requirements which are proved inefficient in securing the results for which they were originally intended, and to incorporate in the specifications only the essential requirements by which the character of the product may be determined with sufficient precision for its actual duty. By making these requirements reasonable and fair, on the one hand as simple and definite as possible without impairing their real value, and on the other hand flexible enough to avoid imposing undue hardship upon the manufacturer who keeps in touch with the best methods available, the result is confidently expected to be a high degree of interested cooperation on the part of both engineer and manufacturer in securing the best grade of material which the present state of science makes practicable.

The American section of that Association in 1901 adopted a series of proposed standard specifications, one of which relates to steel for bridges and buildings and which is recommended for adoption by those who buy such structures. A committee of the Railway Engineering and Maintenance of Way Association is now at work on the same problem, a full agreement having not yet been reached.

With greater uniformity in the physical, chemical and other requirements for steel, as determined by standard tests, the unit stresses to be prescribed for the design of bridges will naturally approach to a corresponding uniformity. To what extent this is desirable may be inferred from the fact that the application of several of the leading specifications to the design of a railroad bridge under a given live load yields results which may vary by an amount ranging from zero to twenty-five per cent. of the total weight.

In the revision of specifications a decided tendency is observed to simplify the design by making an allowance for impact, vibration, etc., by adding certain percentages to the live load according to some well-defined system. It needs but relatively little experience in making comparative designs of bridges under the same loading, to show the advantage of this method over that in which the allowance is made in the unit stresses according to any of the systems usually adopted in such a case. Not only are the necessary computations greatly simplified but the same degree of

security is obtained in every detail of the connections as in the principal members which compose the structure.

Experiments on a large scale are very much needed to determine the proper percentage of the live load to be allowed for the effect of impact, so as to secure the necessary strength with the least sacrifice of true economy. While the extreme economy of material that was formerly practised is not now desirable, since stiffness receives due consideration, some idea of the importance of such an investigation may be gained by considering the magnitude of the industries involved.

In March, the *Railroad Gazette* published a supplement containing a list of bridge projects under consideration. This list was intended to include only the larger steel and stone structures, whether for railroads or highways, the aim being to exclude those that are obviously unimportant. Besides this, the bridges needed on 1,500 new railroad projects recorded in the same supplement are likewise excluded. After excluding both of these classes the list still contains about 1,300 new projects for bridges.

An investigation might also be advantageously made to determine the proper ratio of the thickness of cover plates in chord members which are subject to compression, to the transverse distance between the connecting lines of rivets. The same need exists in regard to the stiffening of the webs of plate girders, concerning which there is a wide variation in the requirements of different specifications.

A movement which has done much good during the past decade and promises more for the future is that of the organization of bridge departments by the railroad companies. The great economy of making one design rather than to ask a number of bridge companies to make an equal number of designs, of which all but one are wasted, is the first advantage; but another of even greater significance in the development of bridge construction is that which arises from the designs being made by those who observe the bridges in the conditions of service and who will naturally devote closer study to every detail than is possible under the former usual conditions. The larger number of responsible designers also leads to the introduction of more new details to be submitted to the test of service, which will indicate those worthy of adoption in later designs. In order to save time and labor and secure greater uniformity in the design of the smaller bridges, some of the railroads prepare standard plans for spans varying by small distances. For the most important structures consulting bridge engineers are more frequently employed than formerly, when so much dependence was placed upon competitive designs made by the bridge companies.

An investigation was recently made by a committee of the Railway Engineering and Maintenance of Way Association in regard to the present practice respecting the degree of completeness of the plans and specifications furnished by the railroads. It was found that of the 72 railroads replying definitely to the inquiry, 33 per cent. prepare 'plans of more or less detail, but sufficiently full and precise to allow the bidder to figure the weight correctly and if awarded the contract to at once list the mill orders for material'; 18 per cent. prepare 'general outline drawings showing the composition of members, but no details of joints and connections'; while 49 per cent. prepare 'full specifications with survey plan only, leaving the bidder to submit a design with his bid.' If, however, the comparison be made on the basis of mileage represented by these 72 railroads, the corresponding percentages are 48, 24 and 28 respectively. The total mile-

age represented was 117,245 miles. A large majority of the engineers and bridge companies that responded were in favor of making detail plans.

The shop drawings, which show the form of the bridge, the character and relations of all its parts, give the section and length of every member, and the size and position of every detail whether it be a reinforcing plate, a pin, a bolt, a rivet or a lacing bar. All dimensions on the drawings are checked independently so as to avoid any chance for errors. The systematic manner in which the drawings are made and checked, and the thorough organization of every department of the shops, makes it possible to manufacture the largest bridge, to ship the pieces to a distant site and find on erecting the structure in place that all the parts fit together, although they had not been assembled at the works.

The constant improvement in the equipment of the bridge shops, and the increasing experience of the manufacturers who devote their entire time and attention to the study of better methods for transforming plates, bars, shapes, rivets and pins into bridges, constitute important factors in the development of bridge construction.

As the length of span for the different classes of bridges gives a general indication of the progress in the science and art of bridge building, the following references are made to the longest existing span for each class, together with the increase in span which has been effected approximately during the past decade.

In plate girder bridges the girders, as their name implies, have solid webs composed of steel plates. A dozen years ago but few plate girders were built whose span exceeded 100 feet, the maximum span being but a few feet longer than this. To-day such large girders are very frequently constructed, and the maximum span has been increased to 126 feet between centers of bearings. This is the span of the large plate girders of the viaduct on the Riverside drive in New York City, erected in 1900. The longest railroad plate girder was erected about the same time on the Bradford Division of the Erie Railroad, its span being 125 feet 2½ inches. The heaviest plate girder is the middle one of a four-track bridge on the New York Central Railroad erected last year near Lyons, N. Y. Its weight is 103 tons, its span 107 feet 8 inches, and its depth out to out 12 feet 2 inches.

The large amount of new construction and the corresponding increase in the weight of the rolling stock have combined to secure a more extensive adoption of plate girders and the designs of many new details for them. These affect chiefly the composition of the flanges, the web splices, the expansion bearings and the solid floor system. Although solid metal floors built up of special shapes were first introduced into this country fifteen years ago, their general adoption has taken place largely within the past decade on account of their special adaptation to the requirements of the elevation of tracks in cities. Solid floors may not only be made much shallower than the ordinary open type, thereby reducing the total cost of the track elevation, but they also permit the ordinary track construction with cross-ties in ballast to be extended across the bridge, thus avoiding the jar which otherwise results as the train enters and leaves the bridge, unless the track is maintained with extraordinary care.

The necessity for bridges of greater stiffness under the increased live loads has also led to the use of riveted bridges for considerably longer spans than were in use six or seven years ago. The use of pin-connected trusses for spans less than about 150 feet is undesirable for railroad bridges, on account of the excessive vibration due to

the large ratio of the moving load to the dead load, or weight of the bridge itself.

While riveted bridges are now quite generally used for spans from 100 to 150 feet, they have been employed to some extent up to 181½ feet. The recent forms of riveted trusses do not, however, conform to the general character of European designs but embody the distinctively American feature of concentrating the material into fewer members of substantial construction. With but rare exceptions the trusses are of the Warren, Pratt and Baltimore types with single systems of webbing. At a distance where the riveted connections cannot be distinguished, the larger trusses have the same general appearance as the corresponding pin bridges.

The recent examples of viaduct construction with their stiff bracing of built-up members and riveted connections exhibit a marked contrast to the older and lighter structures with their adjustable bracing composed of slender rods. The viaduct which carries the Chicago and Northwestern Railroad across the valley of the Des Moines River, at a height of 185 feet above the surface of the river is 2,658 feet long. It was built in 1901, is the longest double-track viaduct in the world, provided those located in cities be excluded, and is an admirable type of the best modern construction. The tower spans are 45 feet long and the other spans are 75 feet long. Four lines of plate girders support the two tracks. Along with this viaduct should be mentioned the Viaduct Terminal of the Chesapeake and Ohio Railway at Richmond, Va., whose length including the depot branch is 3.13 miles. A large part of this is not very much higher than an elevated railroad in cities. The excellent details and clean lines of this substantial structure give it a character which is surpassed neither in this country nor abroad. It may be added that the highest viaduct in this country, and which was rebuilt in 1900, is located seventeen miles from Bradford, Pa., where the Erie Railroad crosses the Kinzua Creek at a height of 301 feet. It has a length of 2,053 feet.

While the elevated railroads which have been built recently, also embody many of the characteristics of the best viaduct construction, special study has been given to improve their esthetic effect. The use of curved brackets, of connecting plates whose edges are trimmed into curves so as to reduce the number of sharp angles, and of rounded corners of posts, constitute some of the means employed. The results are seen in the structures of the Boston Elevated Railroad and in some of the latest construction in Chicago.

The longest span of any simple truss in America is that of the bridge over the Ohio River at Louisville, erected in 1893. Its span center to center of end pins is 546½ feet. Since that time several other bridges of this kind have been built which are considerably heavier, although their spans are somewhat shorter. The most noteworthy of these are the Delaware River bridge on the Pennsylvania Railroad near Philadelphia and the Monongahela River bridge of the Union Railroad at Rankin, Pa., both of which are double-track bridges. The Delaware River bridge was erected in 1896, each one of its fixed spans having a length of 533 feet and containing 2,094 tons of steel. The Rankin bridge was erected in 1900. Its longer span has a length of 495 feet 8⅛ inches between centers of end pins and contains about 2,800 tons of steel, making it the heaviest single span ever erected. It may also be added that the locomotive and train load for which this bridge was designed is the heaviest that has yet been specified.

The recent changes in the details of pin-connected truss bridges have been mainly

the result of efforts to eliminate ambiguity in the stresses of the trusses, to reduce the effect of secondary stresses, and to secure increased stiffness as well as strength in the structure. Double systems of webbing have been practically abandoned so far as new construction is concerned. The simplicity of truss action thus secured permits the stresses to be computed with greater accuracy and thereby tends to economy. Before the last decade very few through bridges and those only of large span were designed with end floor beams in order to make the superstructure as complete as possible in itself and independent of the masonry supports. Now this improved feature is being extended to bridges of small spans. Similarly dropping the ends of all floor beams in through bridges so as to clear the lower chord and to enable the lower lateral system to be connected without producing an excessive bending movement in the posts has likewise been extended to the smaller spans of pin bridges and is now the standard practice. The expansion bearings have been made more effective by the use of larger rollers, and of bed plates so designed as to properly distribute the large loads upon the masonry. In the large spans of through bridges the top chord is curved more uniformly, thereby improving the esthetic appearance. These chords are also given full pin bearings, thus reducing the secondary stresses.

The stiffness of truss bridges has been secured by adopting stiff bracing in the lateral systems and sway bracing, instead of the light adjustable rods formerly used. At the same time adjustable counter ties in the trusses are being replaced in recent years by stiff ones, while in some cases the counters are omitted and the main diagonals designed to take both tension and compression.

Some of the same influences referred to above have led to much simpler designs for the portal bracing by using a few members of adequate strength and stiffness similar in general character to those of the trusses.

Such steady progress in the design and construction of railroad bridges of moderate span has, unfortunately, no adequate counterpart in highway bridges. The conditions under which highway bridges are purchased by township and county commissioners are decidedly unfavorable to material improvements in the character of their details. It is a comparatively rare occurrence that the commissioners employ a bridge engineer to look after the interests of the taxpayers by providing suitable specifications, making the design, inspecting the material, and examining the construction of the bridge to see that it conforms to all the imposed requirements. These provisions are only made in some of the cities, and accordingly one must examine the new bridges in cities to learn what progress is making in highway bridge building.

The lack of proper supervision in the rural districts and many of the smaller cities results in the continued use of short trusses with slender members built up of thin plates and shapes, whose comparatively light weight causes excessive vibration and consequent wear, as well as deterioration from rust. Under better administration plate girders would be substituted for such light trusses, making both a stiffer structure and one more easily protected by paint. The general lack of inspection and the consequent failure to protect highway bridges by regular repainting will materially shorten their life and thereby increase the financial burden to replace them by new structures. Some progress has been made in adopting riveted trusses for the shorter spans for which pin-connected trusses were formerly used, but the extent of this change is by no means as extensive as it should be, nor equal to the corresponding advance in railroad bridges.

The channel span of the cantilever bridge over the Mississippi River at Memphis, Tenn., is the longest one of any bridge of this class in America. It measures 790½ feet between centers of supports. This bridge was finished in 1890, the same year that marked the close of the seven-year period of construction and erection of the mammoth cantilever bridge over the Firth of Forth in Scotland. A number of cantilever bridges have been built since then, but most of them have comparatively short spans. There is one now under construction over the Monongahela River in Pittsburgh, and which is expected to be finished this year, whose span is to be a little longer than that of the Memphis bridge. It is on the new extension of the Wabash Railroad system, and the distance between pier centers is 812 feet.

But there is another one being built which will not only have a longer span than any other cantilever bridge in this country, but longer than that of any other bridge whatsoever. It is located near Quebec, Canada, and its channel span over the Saint Lawrence River is to have the unprecedented length of 1,800 feet or nearly a hundred feet longer than that of the Forth cantilever bridge and two hundred feet longer than the Brooklyn suspension bridge. The towers will have a height of 360 feet above high tide. It will accommodate a double-track railroad, besides two electric railway tracks and highways. In the piers the courses of masonry are four feet high and individual stones weigh about fifteen tons each. The character of its design and the simplicity of its details will permit its construction with unusual rapidity and economy for a bridge of this magnitude. Several other cantilever structures whose largest spans range from 600 to 671 feet are either now or soon will be under construction.

The Brooklyn bridge, completed in 1883, is still the largest suspension bridge in the world, its span being 1,595½ feet. More people cross this bridge than any other in any country. The New East River bridge, which is now being built, has a span of 1,600 feet, and its capacity will be very much greater than that of the Brooklyn bridge. Each of its four cables has a safe strength of over 10,000,000 pounds in tension.

One of the most interesting developments relating to the subject under consideration is the construction of a considerable number of metallic arch bridges in recent years and the promise of their still greater use in the future. On account of their form they constitute one of the handsomest classes of bridges.

The first important steel bridge in the world was completed in 1874. It is the arch bridge which in three spans crosses the Mississippi River at St. Louis. Its arches are without hinges and their ends are firmly fixed to the piers. This is one of the most famous bridges in existence. For a long time after its construction no metallic arches were erected in this country, although many were built in Europe. In 1888, however, the highway bridge across the Mississippi River at Minneapolis was erected, consisting of two spans of 456 feet each and which still remains the longest span of any three-hinged arch. The following year the Washington bridge over the Harlem River in New York city was completed. It consists of two spans of 510 feet in the clear and has the largest two-hinged arch ribs with solid web plates.

These were followed by a number of arches of various types, the most noted of which are the two arch bridges over the Niagara River. The first one is a spandrel-braced, two-hinged arch with a span of 550 feet and replaced the Roebling suspension bridge in 1897. It accommodates the two tracks of the Grand Trunk Rail-

road on the upper deck and a highway on the lower deck. The other bridge has arched trusses with parallel chords and two hinges. It replaced the Niagara and Clifton highway suspension bridge in 1898, and as its span is 840 feet, it is the largest arch of any type in the world. The manner in which this arch was erected furnishes an illustration of the effort which is made by engineers to conform the actual conditions so far as possible to the theoretic ones involved in the computation of the stresses. Since the stresses in an arch having less than three hinges are statically indeterminate, stresses of considerable magnitude may be introduced into the trusses if the workmanship be imperfect, the supports not located with sufficient precision, and the arch closed without the proper means and care.

The Niagara and Clifton arch was first closed as a three-hinged arch and then transformed into a two-hinged arch by inserting the final member under the sum of the computed stress due to the weight of the truss, and that due to the difference between the temperature at which the closure was made and that assumed as standard in the stress computations. This stress was secured in the member by inserting it when the hydraulic jack which forced apart the adjacent ends of the shortened chords registered the required amount of pressure. The arch had been erected as a pair of cantilevers from each side extending 420 feet out beyond the supports, and when the closure was made the two arms came together within a quarter of an inch of the computed value. Such a result involving the 'accuracy of the calculation and design of the entire steel work, the exactness with which the bearing shoes or skewbacks were placed, and the perfection of the shopwork' has been truly characterized as phenomenal.* In order to reduce secondary stresses to a minimum the members were bolted up during the cantilever erection and the bolts replaced by rivets after the closure of the arch rib.

The past decade witnessed the introduction and extensive development of arches of concrete and of concrete-steel construction. In the latter kind a small amount of steel is imbedded in the concrete in order to resist any tensile stresses that may be developed. During this period more than 150 concrete steel bridges have been built in this country. In the same year in which the largest metallic arch was completed, the five concrete-steel arches of the bridge at Topeka, Kansas, were finished. The largest one has a span of 125 feet and still remains the largest span of this type in America, although it has been exceeded in Europe. Considerably larger spans are to be built this season, while others are included in the accepted design for the proposed Memorial bridge at Washington.

It is the smaller steel structures which are destined more and more to be replaced by arches of this material. The steel bridges require repainting at frequent intervals, constant inspection, occasional repairs and finally replacing by a new structure after a relatively short life, on account of rust and wear, unless it is required even sooner on account of a considerable increase in the live load. The concrete arch requires practically no attention except at very long intervals.

The safety of operating the traffic makes it desirable to have as few breaks as possible in the regular track construction of a railroad, and this constitutes an additional reason why concrete or stone arches are being substituted for the smaller openings. The decreasing cost of concrete tends to an extension of this practice to openings of increasing size. Last year, however, a bridge was completed which marks a decided departure from previous practice.

* *Engineering News*, August 4, 1898.

The Pennsylvania Railroad built a stone bridge, consisting of 48 segmental arches of 70 feet span, at the crossing of the Susquehanna River at Rockville, Pa. It is 52 feet wide, accommodates four tracks and cost a million dollars. This bridge has not only the advantage of almost entirely eliminating the cost of maintenance, but it also has sufficient mass to withstand the floods which occasionally wreck the other bridges on that river. This year the same railroad is building a similar bridge over the Raritan River at New Brunswick, N. J.

Of movable bridges the largest swing span existing was erected in 1893 at Omaha over the Missouri River. Two years later a four-track railroad swing bridge was built by the New York Central Railroad over the Harlem River in New York city, which is only 389 feet long between centers of end pins, but which weighs about 2,500 tons and is accordingly the heaviest drawbridge of any class in the world.

During the past decade a remarkable development was made in drawbridge construction by the modification and improvement of some of the older types of lift bridges and the design of several new types. At South Halstead Street a direct-lift bridge was built in 1893 over the Chicago River, in which a simple span 130 feet long and 50 feet wide is lifted vertically 142½ feet by means of cables to which counterweights are attached. Formerly, only very small bridges of this kind were used, as those, for instance, over the Erie Canal.

In 1895 a rolling lift bridge over the Chicago River was completed. In this new design as each leaf of the bridge rotates to a vertical position it rolls backward at one end. When closed the two leaves are locked at the center, but they are supported as cantilevers. This form has been found to have so many advantages for the crossings of relatively narrow streams, where an unobstructed water way is required and the adjacent shores are needed for dock room, that a score of important structures of this class have been built in different cities. The largest span that has been designed is 275 feet between centers of supports, while the widest one is to accommodate eight railroad tracks crossing the Chicago Main Drainage Canal.

About the same time and under similar conditions another type of bascule bridge was built at Sixteenth Street, Milwaukee, in which, as each leaf moves toward the shore, one end rises and the other falls, so that its center of gravity moves horizontally, thus requiring a very small expenditure of power to operate the bridge.

Several improved forms of hinged-lift bridges have also been designed and built in Chicago and elsewhere. In a small bridge erected in 1896 on the Erie Railroad in the Hackensack meadows there is only a single leaf hinged at one end and lifted by a cable attached to the other end. The counter weight rolls on a curved track so designed as to make the counter balance equally effective in all stages of opening and closing the bridge.

A novel bridge is now being built over the ship canal at Duluth which is different from any other type in this country. The general scheme is similar to that of a design made by a French engineer who built three of the structures in different countries. It consists of a simple truss bridge 393 feet 9 inches long, supported on towers at a clear height of 135 feet above high water. Instead of supporting the usual floor of a highway bridge it supports the track of a suspended car which is properly stiffened against wind pressure and lateral vibration, the floor of the car being on a level with the docks. This ferry is operated by electricity. The loaded car, its hangers, trucks and machinery weigh 120 tons. In the French design a suspension

bridge was used instead of the simple truss bridge.

A bridge is being built across the Charles River between Boston and Cambridge that deserves especial mention and marks a decided advance in the growing recognition on the part of municipal authorities of the importance of esthetic considerations in the design of public works. It consists of 11 spans of steel arches whose lengths range from 101½ to 188½ feet. Its width is 105 feet between railings. It is claimed that this bridge 'will be not only one of the finest structures of its kind in this country, but will be a rival of any in the old world.' Its length between abutments is 1,767½ feet, and it is estimated to cost about two and a half millions of dollars.

The problems incident to the replacing and strengthening of old bridges frequently tax the resources of the engineer and demonstrate his ability to overcome difficulties. Only a few examples will be cited to indicate the character of this work. In 1900 the Niagara cantilever bridge had its capacity increased about 75 per cent. by the insertion of a middle truss without interfering with traffic. In 1897 the entire floor of the Cincinnati and Covington suspension bridge was raised four feet while the traffic was using it. It may be of interest to state that the two new cables, 10½ inches in diameter, which were added to increase the capacity of the bridge, have just about three times the strength of the two old ones, 12⅓ inches in diameter, and which were made a little over thirty years before. In the same year the old tubular bridge across the Saint Lawrence River was replaced by simple truss spans without the use of false works under the bridge and without interfering with traffic. On May 25 of this year the Pennsylvania Railroad bridge over the Raritan River and canal at New Brunswick, N. J., was moved sidewise a distance of 14½ feet. Five simple spans 150 feet long and a drawbridge of the same length, weighing in all 2,057 tons, were moved to the new position and aligned in 2 minutes and 50 seconds. The actual time that the two tracks were out of service were respectively 15 and 28 minutes. On October 17, 1897, on the same railroad near Girard Avenue, Philadelphia, an old span was moved away and a new one, 235 feet 7 inches long, put in exactly the same place in 2 minutes and 28 seconds. No train was delayed in either case.

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*REPORT OF PROGRESS OF THE NEBRASKA STATE GEOLOGICAL SURVEY AND THE MORRILL GEOLOGICAL EXPEDITION OF 1901.**

IN spite of the phenomenal heat of the summer of 1901, which was of such intensity and duration that active work in the field was finally suspended, enough progress was made to justify the presentation of the matter to this society. It should be reported, first of all, that a request for funds, amounting to twelve hundred dollars, for publishing the first reports of the state geological survey, was presented to the Legislature, and was passed April 1, 1901, without comment or dissent. This may be recorded as the first sum voted by the state for the examination and publication of its resources; and, though small, it is particularly large at this juncture, for it makes possible the initial work of the state survey. Unfortunately the passage of the bill, by the Legislature, was a little too late to enable us to avail ourselves of a long-standing offer from the U. S. Geological Survey to cooperate in doing geological work in Nebraska, as soon as the state evidenced its recognition of the importance of a geological survey by offering

* Reported to the Nebraska Academy of Science, January 25, 1902.